

## SECTION 4

### CTD Transect Data

Conductivity, temperature, and depth (CTD) transects were conducted monthly between February and July, 2001 at 5 locations in Puget Sound for the MOSS project (Figure 4-1): Possession Sound, Edmonds, Point Wells, West Point and Alki. Data collected by CTD casts included depth (m), temperature ( $^{\circ}\text{C}$ ), salinity (PSS), photosynthetically active radiation ( $\mu\text{mol}/\text{m}^2\text{s}$ ), chlorophyll-*a* ( $\text{mg}/\text{m}^3$ ), and dissolved oxygen ( $\text{mg}/\text{L}$ ). Density (sigma-t) was calculated monthly from measurements of temperature and salinity. Turbidity (FTU) was measured once in July. The data are presented as vertical profiles in Figures 4-2 to 4-20. Each graph represents a cross-sectional view of the water column as viewed to the north. The horizontal axis represents distance from the western shoreline and the terminus of the horizontal axis represents the eastern shoreline of Puget Sound.

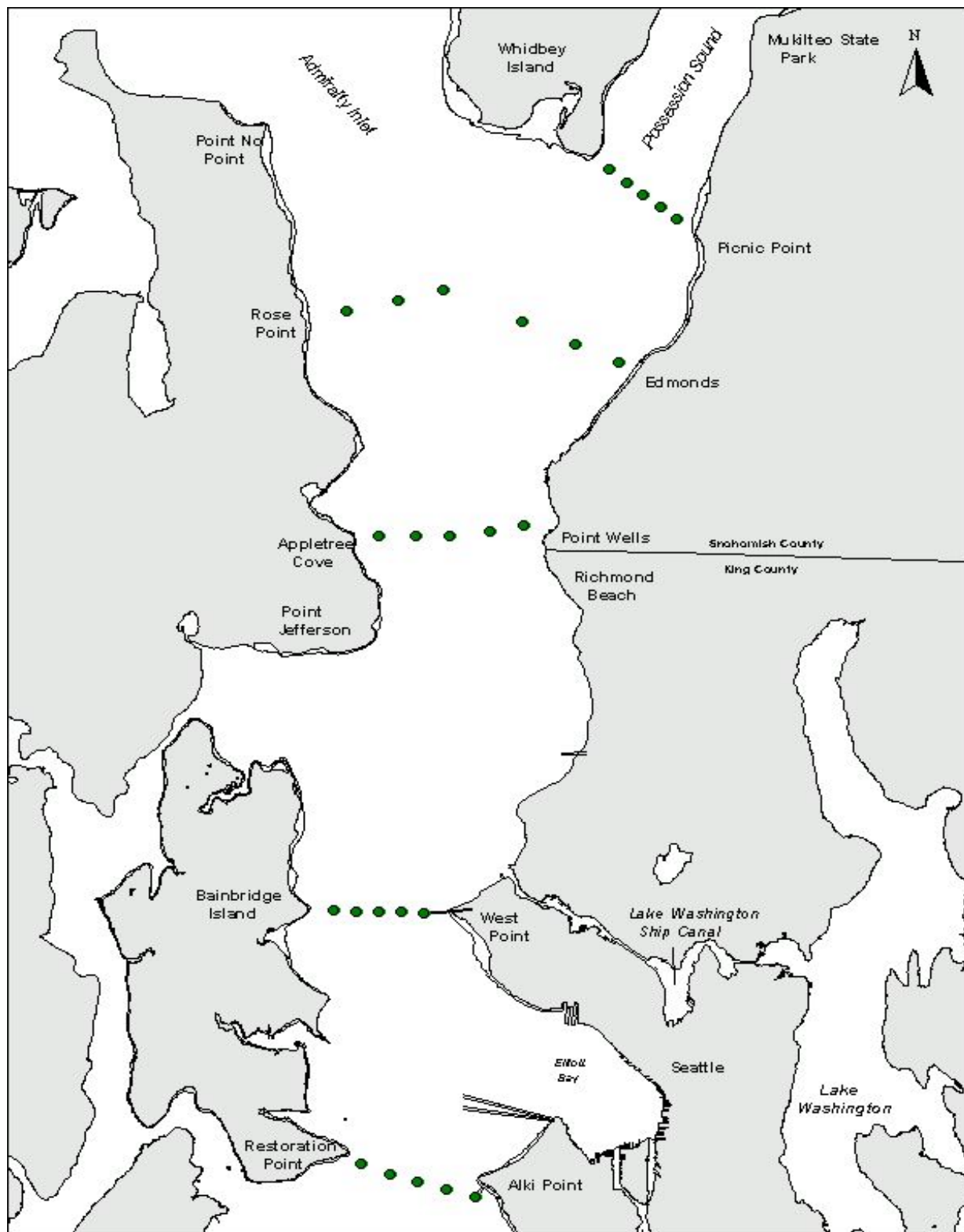
#### 4.1 Temperature

The vertical temperature structure in 2001 exhibited typical seasonal patterns (Figures 4-2 to 4-4). The water column was essentially isothermal (i.e., the temperature was uniform throughout) from February through May, with mean temperatures ranging from 8.0 to 8.3  $^{\circ}\text{C}$ . Thermal stratification started to develop in May, becoming progressively marked in June and July. Surface waters increased to temperatures above 13 or 14  $^{\circ}\text{C}$  at all locations in July, the last month sampled. The month of August typically exhibits the highest water temperatures with continued stratification of the water column (data not available for 2001).

Temperature profiles at the entrance to Possession Sound in northern Puget Sound indicated well developed thermal stratification in July with warmer temperatures than the previous two years. As in 1999 and 2000, the temperatures recorded in the Possession Sound surface water were the highest temperatures among the five locations sampled. These higher temperatures are a result of solar heating and less dynamic waters in Possession Sound.

Slightly warmer surface waters on the eastern shoreline (mainland) than on the western shoreline were observed in Possession Sound as well as in Alki transects. This east-west difference in thermal structure may be a result of a difference in flow across the basin. Colder oceanic water may be entering the Sound along the western side and warmer sound water exiting the Sound along the eastern shore (Ebbesmeyer et al., 2001).

Temperature profiles along the Point Wells and Edmonds transects indicated the presence of warmer surface waters along the western shoreline (Kitsap Peninsula) in June and July, differing from Possession Sound and Alki, and differing somewhat from the thermal patterns observed in 1999 and 2000. The West Point transect exhibited a flat thermal structure in July, in agreement with observations from previous years.



**Figure 4-1. CTD Transect Station Locations**

## 4.2 Salinity

Salinity along the Puget Sound transects ranged from 24.3 to 30.7 PSS during the months sampled (February – July) (Figures 4-5 to 4-7).

Salinity stratification of the water column occurs when a layer of low salinity surface water persists on top of higher salinity oceanic water. This type of stratification is typically strongest in late spring and early summer as a result of runoff from snowmelt and is readily apparent at all locations profiled in 2001. A second peak in stratification may occur in late fall or winter as a result of local precipitation.

As in previous years, Possession Sound salinity profiles during 2001 were characterized by a persistent lens of low salinity surface water. This low salinity water represents the freshwater input of the Snohomish River located at the northern reaches of Possession Sound. Beneath the lens of low salinity water the salinity structure remained flat, i.e., without marked east-west variations, as is characteristic of salt wedge type estuarine systems. The lowest salinity encountered during 2001 was recorded at this location in April (24.3 PSS).

Salinity stratification along the Point Wells and Edmonds transects exhibited a pattern similar to the one seen in the temperature profiles. In March, the halocline (the layer of water with a rapid change in salinity) was somewhat deeper along the eastern shoreline (mainland), indicating influx of more saline ocean water on the western side of the basin and outflow of less saline Puget Sound water along the eastern shore. This pattern was found to persist throughout the summer in 1999 and 2000. In 2001, however, the salinity pattern was reversed in the following months, giving way to a marked deepening of low salinity waters along the western shoreline (Kitsap Peninsula) in June and July.

The West Point and Alki transects were only slightly stratified in spring and summer, with a deeper layer of low salinity water on the eastern shoreline.

## 4.3 Density

Density profiles are a function of both salinity and temperature, salinity having a greater impact on density than temperature. As such, the vertical structure of the density will closely mimic the salinity and temperature profiles discussed above. Density profiles are shown in Figures 4-8 to 4-10.

The density profiles in Possession Sound were generally flat with a slight deepening of low density waters towards the eastern shoreline in July. The cooler, denser water at depth is indicative of oceanic water flowing up into Possession Sound with the warmer, fresher water flowing out at the surface while moving towards the east.

The density profile along the Point Wells and Edmonds transects exhibited a slope downward to the west, which was also seen in the temperature and salinity profiles. This pattern is somewhat different to profiles from previous years and is not explained by the accepted Puget Sound circulation pattern whereby water flows out along the eastern shore while denser oceanic water flows in along the western shore. Only the Alki transects exhibited density profiles consistent with this circulation pattern.

## 4.4 Photosynthetically Active Radiation

Photosynthetically active radiation (PAR) is a measure of the amount of light (number of photons) available for photosynthesis and is a key factor for the growth of phytoplankton. PAR levels in the marine environment are highly variable, depending on season, weather conditions, and depth. Because local weather conditions or the occasional passing of a cloud can dramatically alter measured PAR values, the data presented are discussed only in a general manner (Figures 4-11 to 4-13).

Surface light levels during the winter months were 2-10 times lower than summer surface levels. Since light attenuates relatively quickly as it passes through the water column, data were only collected to a depth of 30 meters. Although less light is available in the winter months, light penetration is typically highest during these months due to the absence of phytoplankton cells (i.e. the water is clearer) and lowest during the spring and summer when phytoplankton absorb a significant portion of the light penetrating the water.

## 4.5 Chlorophyll-*a*

Chlorophyll-*a* is the primary pigment present in all photosynthetic cells. The concentration of chlorophyll-*a* (as indicated by the measure of fluorescence) in a water sample is commonly used as a measure of the density of phytoplankton in that sample.

Chlorophyll-*a* reached the highest concentrations along all transects during the summer months; concentrations were low both during the winter and at depths greater than 50 m during all seasons (Figures 4-14 to 4-16). This pattern in primary production is typical in Puget Sound and of temperate nearshore areas.

The Possession Sound, Point Wells, West Point and Edmonds profiles all indicate one distinct bloom ( $>30 \text{ mg/m}^3$ ) in May with decreasing population densities in June. Two distinct blooms - in May and July - were observed the two previous years in Possession Sound and Point Wells. It is likely that a second peak developed later in the summer of 2001. Possession Sound and Point Wells had the densest blooms, with chlorophyll-*a* concentrations  $>60 \text{ mg/m}^3$ . Both the Point Wells and the Edmonds blooms extended down to greater depth on the western shoreline (Kitsap Peninsula), suggesting that phytoplankton growth is stimulated by the input of nutrient rich inflowing oceanic water.

The chlorophyll-*a* distribution along the Edmonds transect indicates very high chlorophyll-*a* levels along the shorelines and very low levels towards the center of the transect. This pattern has been observed in previous years and suggests the presence of upwelling at this location. It appears as though there was an instrument malfunction during sampling of the Alki transect in April that was not evident for the other transects sampled.

## 4.6 Dissolved Oxygen

The Washington State Department of Ecology considers a dissolved oxygen (DO) concentration below 5.0 mg/L to be an indicator of depressed water quality (Ecology, 1998). Depressed DO concentrations can result from the natural cycles of primary production or can be induced by the anthropogenic introduction of nutrients to the system. DO concentrations typically start decreasing at depth in early summer as dead organic matter produced from surface blooms travels through the water column and settles at the bottom, reaching minimum values during late fall and early winter. Since CTD profiling during 2001 was limited to the months of February through July it did not include the time of year when DO is known to reach critically low values (Figures 4-17 to 4-19).

Possession Sound, Point Wells, West Point and Edmonds DO profiles mirrored chlorophyll-*a* profiles, with summer surface bloom areas exhibiting higher DO concentrations as a result of photosynthetic oxygen evolution by phytoplankton.

Dissolved oxygen concentrations at or slightly below 5.0 mg/L were observed in Possession Sound and Edmonds in July. Possession Sound historically has low DO concentrations due to the limited circulation and high riverine input of organic matter.

## 4.7 Turbidity

Changes in water column turbidity can be explained by the presence of suspended inorganic particulate material and floating, planktonic organisms. Turbidity is usually greatest during the winter months when there is high precipitation runoff. Increased turbidity during spring and summer is associated with snowmelt runoff carrying particulates and increased primary production in surface waters. Turbidity measurements in 2001 were limited to the month of July (Figure 4-20) and thus did not include the times of year when turbidity is known to reach maximum values.

In July turbidity was low at all five locations. Evident in all transects is an increase in turbidity along the bottom, resulting from trapping and suspension of benthic particulate material. This layer was thickest in Possession Sound.

## 4.8 Summary of CTD Data

CTD data for 2001 were collected from February to July only. This timeframe is adequate to assess key seasonal changes occurring during spring and early summer related to increases in temperature, light intensity and daylength, yet it precludes assessment of processes that occur later in the year, such as low DO due to the decay of organic matter or increased turbidity from runoff.

The 2001 CTD transects were only partially consistent with the suspected circulation pattern of the Puget Sound Central Basin and Possession Sound. Oceanic water entering the system along the western edge of Admiralty Inlet is expected to decrease the depth of the isoclines along the western edge of the transects. In other words, the top layer of warmer, low salinity water in which algal blooms develop in spring and summer would be thinner on the west side than on the east side. This pattern was observed for the southernmost, Alki transect only, whereas an inverse pattern was evident for Edmonds and Point Wells. The transect at the entrance to Possession Sound was generally consistent with previous years, but indicates a concentration of surface water along the eastern instead of the western shoreline.

Two measures of biological activity, chlorophyll-*a* and dissolved oxygen, exhibited patterns typical of the Puget Sound region. Primary productivity, measured as changes in chlorophyll-*a* and DO in surface waters, peaked in May and was followed by a decrease in DO at depth. Unlike the previous two years, a second peak had not yet developed by July of 2001.